

Open Innovation and Social Network Analysis ³

Ana Clara Cândido (a.candido@campus.fct.unl.pt), IET/CESNova, Faculty of Sciences and Technology, Universidade Nova de Lisboa

Abstract

In this work we propose the use of Social Network Analysis to understand the positioning of the concept of Open Innovation in the literature, offering thereby a complementary approach to existing literature review up to now. The main motivation of this network analysis is to contribute to the understanding of the concept of Open Innovation, with its spread to different areas of knowledge over the years and its relationship with other concepts in the literature. Some 403 articles published in the database of the Science Direct during the years 2003 to 2011 were analyzed. The data was collected separately by year, considering the following information: journals in which the articles were published; countries of origin of the articles' authors, keywords of these articles and year of publication. The results reveal the intense growth of the use of the words "Open Innovation" in articles from different areas of knowledge, as well as its increasing interconnection with other concepts, allowing the understanding of its diffusion in the literature.

Key-words: Open Innovation; Network Analysis; Social Network

JEL codes: M19; O30

³ The present article is based on the report for the Doctoral Conference of the PhD programme in Technology Assessment, held at FCT-UNL Campus, Monte de Caparica, July 9th, 2012. The PhD thesis has the supervision of Prof. Cristina Sousa (ISCTE-IUL), and co-supervision of Prof. José Cardoso e Cunha (FCT-UNL).

Introduction

In the last years there has been a pronounced presence of the Open Innovation Model of scientific studies and also in innovation strategies adopted by executives, managers and entrepreneurs.

The concept emerged through the studies of Henry Chesbrough, namely to the publication of the work entitled "*Open Innovation: the New Imperative for Creating and Profiting from technology*" (2003). The issue became polemic in academic and business environment for the new ideas about the innovation practices in multinational companies cited by the author. This open innovation model goes against some principles followed by companies during the XX Century. If previously, the idea was a model of closed innovation, now the strategic would have changed towards a practice of collaboration between companies that join forces to become more competitive and thus turning into an open innovation model.

Some of the questions raised in the literature of Open Innovation had already been perceived by others authors previously of the formulation of the concept per se. Dahlander and Gann (2010) after undertaking an extensive literature review found some evidence to the concept currently used. Particularly in the works of Cohen and Levinthal (1990) on absorptive capacity; Teece (1986; 1991) on complementary assets and exploration vs. exploitation discussion; Von Hippel's (1986) on the fundamentals of customers' integration in the innovation process; among other examples that could be cited. Thus, we might ask ourselves what really is new in the concept of Open Innovation and this question would make us recognize that Chesbrough (2003) did an excellent work of integrating all these management theories behind the concept and we could conclude that, after all, it is positive that the exchange of internal and external knowledge happens.

The aim of this study is to realize a theoretical review of the topics on the Open Innovation Model, besides showing the main differences between Closed and Open Innovation. We also propose the use of Social Network Analysis to understand the positioning of the concept of Open Innovation in the literature, offering thereby a complementary approach to existing literature review up to now. This network analysis has the main motivation to contribute to the understanding of the concept of Open Innovation, with its spread to different areas of knowledge over the years and its relationship with other concept in the literature.

Some 403 articles published in the database of the Science Direct during the years 2003 to 2011 were analyzed. The data was collected separately by year, considering the following information: journals in which the articles were published; countries of origin of the articles' authors, keywords of these articles and year of publication.

Based on the keywords identified in each article, adjacency matrices of keywords were constructed, initially year by year and at a later stage taking into consideration the whole period in analysis. Having resorted to the software UCINET and Netdraw the networks of keywords were analyzed and represented graphically.

The results reveal the intense growth of the use of the words "Open Innovation" in articles from different areas of knowledge, as well as its growing interconnection with other concepts, allowing the understanding of its diffusion in the literature.

Open Innovation and Closed Innovation

Throughout the years can observe the change in thinking "Innovation". The predominant model until 90s, Closed Innovation was characterized by the ability to use internal knowledge as the only way a company gain competitive advantage against competitors. The idea defended by this model predominated during many years mentality of intrinsically managers of small, medium and large organizations. Many studies that deal directly or indirectly themes of competitiveness and business strategies have been developed over the years (Cohen and Levinthal, 1990; Teece, 1986, 1991; Von Hippel's, 1986) and had their contribution to the formulation of the open innovation model. The new model is called Open Innovation, gathering multiple reflections of theories (innovation management) that already existed. Assuming the idea that a company cannot innovate in isolation, rather, it must have a strategy of openness (as we will deepen next opening session types), thus opposing the ideas defended by the then traditional model (Closed Innovation).

The Open Innovation defends the incorporation of knowledge through the pursuit of externally developed technologies, in order to efficiently use the available knowledge, creativity and experience of the departments of R&D. Thus, it is believed that the practice of sharing knowledge with other companies, universities, research centers will provide a leap in business performance. In the words of Chesbrough (2006: 2):

"The Open Innovation paradigm can be understood as the antithesis of the traditional vertical integration model where internal research and development (R&D) activities lead to internally developed products that are then distributed by the firm. (...) Open Innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively".

The idea of join forces with competitors would be something completely absurd to affirm when the Closed Innovation model still predominates. However, the studies that support the use of knowledge available outside the boundaries of the company confirms that even companies that compete in a given market can benefit from Open Innovation. Even with the approval and consolidation model, some companies still appear to have fears in partnership with its own competitors. Here one must emphasize two important issues should be borne into account the stage of the process in which the partnership

will can be interesting for both and the specificities of each industry / technology.

Christensen et al. (2005) to the deal the evidence of industrial dynamics of Open Innovation model claims that the success of this model may differ transversally of technologies and industries. It should be emphasized that currently there are several empirical studies dealing with different cases (organizations, technologies, industries, etc.) And situations that seek to analyze the effect of Open Innovation or the absence thereof, for example: DSM (Kirschbaum, 2005); IBM (Chesbrough, 2007) and Procter & Gamble (Huston and Sakkab, 2006). However, given the rapid transformations that occur in an increasingly globalized world, are necessary more empirical studies that address the specifics of the Open Innovation Model. This is because the empirical studies are considered relevant mechanisms for the scientific development of various areas of knowledge. That happens mainly in areas constantly changing technological such as ICT (Information and Communication Technology). In this sense, Huizingh (2011: 8) draws attention to the needs for studies on the subject "... there are still many open innovation issues that we need to understand better, in order to absorb the new concept fully in integrated (innovation) management theories and existing management toolkits. We still lack knowledge about how to do it and when to do it".

Table 1 presents some sentences (Chesbrough, 2006) that represent characteristics observed in Closed Innovation and Open Innovation Models. The table presents sentences that distinguish clearly how managers think about strategic decisions in these two environments.

Table 1 – Characteristics of Closed Innovation and Open Innovation Models

Closed Innovation	Open Innovation
The best people in the area work for us	We work with talented people inside and outside the organization
To profit from R&D, we have to discover, develop and commercialize on its own	External R&D can increase the value significantly. The internal R&D is necessary for yourself to take part of this value
The company that take innovation to market first will win	Building business models better is more important than come first
If we create more and better ideas to market, will win	If we do better use of internal and external ideas, will win
We should control our IP, so that our competitors do not profit from our ideas	We must benefit for others to use our IP and we acquire outsourcing technologies that bring us benefits

Source: Adapted from Chesbrough (2006)

Strategies on Open Innovation

For all objectives of competition in the market to be achieved it is necessary to decide on the strategies to be adopted to reach where wants to reach. This is a constant current challenge in the routine of managers. The competition, sometimes disloyal, requires constant dynamism and business vision in the medium and long term.

As already affirmed Christensen (2003) nor even the large companies has the assurance market leadership. In this scenario of competition, as discussed in the previous session, the Open Innovation Model gained space and analyzed with more attention.

According to Vanhaverbeke and colleagues, "the role of open innovation can only be understood within this broad strategic setting: companies engage in open innovation to create value for customers in new ways and to create a more profitable business" (Vanhaverbeke et al., 2012: 14).

In addition to the analysis that distinguish process of the open innovation and closed innovation, one can also measure and classify the degree of opening when the case it is a process having the characteristics of innovation open.

Chesbrough (2006) identify two essential functions of business models: create and capture part of the value created. The companies that have a posture of openness of their ideas and knowledge form a kind of ecosystem of innovation. From this it are more likely to acquire the knowledge available externally, as confirmed through various empirical studies relevant are benefited with this dynamic environment knowledge. Previously to findings made by the father of the concept of Open Innovation, Cohen and Levinthal's (1989) suggested the dual role of R&D: develop new internally and create absorptive capacity to locate and evaluate the development outside the boundaries of the firm. When speaking on the existing strategies in open innovation model, it is possible to observe the various activities and processes of opening. Thus, we analyzed, for example, if we are talking about activities: inbound (outside-in), outbound (inside out) or dual activity (the two dimensions used either exclusively, sometimes in association). Each of these activities can have degrees of opening larger or smaller. An interesting starting point for this analysis is proposed by Dahlander and Gann (2010) by presenting four words considered key to analyzing the context: Acquiring, Sourcing, Selling and Revealing, relating them quite accurately with the concepts of inbound and outbound:

(1) Inbound process: *Acquiring e Sourcing*

(2) Outbound process: *Selling e Revealing*

Dahlander and Gann underline the following: "Inbound open innovation refers to internal use of external knowledge, while outbound open innovation refers

to external exploitation of internal knowledge” (Dahlander and Gann, 2010: 4).

The authors also distinguish these processes in pecuniary and non-pecuniary, as observed in Table 2.

Table 2 – Structure of different types of opening

	Inbound innovation	Outbound innovation
Pecuniary	Acquiring	Selling
Non-pecuniary	Sourcing	Revealing

Source: Dahlander and Gann (2010, p. 702).

The Outbound activities deal of types opening in which internal resources can be made available to the external environment. Companies can do this in two forms: *Revealing*, using formal methods (patents, trademark or copyright protection) and informal methods (lock-ins and lead times) and *Selling*, commercialization of Technologies through sale or licensing resources developed by others organizations.

In the case of Inbound activities the reverse flow occurs, there are two ways to do: Sourcing, the companies can use external sources of innovation available outside their internal boundaries. The case of R&D laboratories can be an example of sourcing, these are means to absorb external knowledge and mechanisms to assess, internalize and make them fit with the internal process. The other way refers to Acquiring, this kind openness companies acquire inputs to the innovation process through the market. The acquisition of valuable resources to an innovation process requires experience (Dahlander e Gann, 2010).

Nevertheless to the benefits of knowledge sharing, when in situations of high degree of openness, companies need a certain degree of control over the number of elements of their networks of collaborations (von Zedtwitz and Gassmann, 2002). The understanding of these two dimensions is described by Chiaroni et al (2011, p. 35) below:

- (i) *inbound* or outside-in Open Innovation, which is “the practice of leveraging the discoveries of others” and entails the opening up to, and establishment of relationships with, external organisations with the purpose to access their technical and scientific competences for improving the firm’s innovation performance;
- (ii) *outbound* or inside-out open innovation, which suggests that “rather than relying entirely on internal paths to market, companies can look for external organisations with business models that are better

suites to commercialize a given technology”

Still with the goal of provide a better understanding of the ratings openness Lichtenthaler and Lichtenthaler (2009) bring another perspective to explain the flow of knowledge in open innovation model. Thus, the main contribution of the authors is based on the distinction of three different processes: *knowledge exploration*, *retention* e *exploitation*. To talk about these three processes is necessary to refer the existing relationship to the dimensions of *inbound* e *outbound* that already mentioned above.

The Inbound dimension – outside-in – companies benefit from the knowledge available outside their own borders. This action corresponds to the process “*Knowledge exploration*” which refers to those activities designed to looking for new knowledge to the internal environment.

Moreover, the Outbound dimension – outside out – companies that have certain knowledge strategically can make it available for other companies to use it, the existing technological capabilities can be used outside the boundaries of the firm. The process which corresponds to this dimension is the “*Knowledge Exploitation*” that is the use and maintenance of that knowledge already acquired.

The companies can choose adopt open innovation strategies that use activities within the dimensions: inbound and outbound, exclusively or can even practice activities of the two dimensions.

Huizingh (2011) argues that empirical studies have consistently concluded that companies use more activities the dimension Inbound than that Outbound. The author suggests that this occurs because companies fail to capture the potential benefits.

Perhaps an additional explanation for this situation is that many companies have recognized the advantages of open innovation still have fears about the effects of using his knowledge as a strategic asset supply.

Observing the flow of activities open innovation could be said that the performance of inbound activities by an organization involve in conducting outbound activities by other organizations (Chesbrough and Crowter, 2006). If so then, what would be the explanation for the existences of more activities inbound than outbound? In principle it would seem that should be at the same intensity, no? Indeed, the answer to the last question is not.

If we analyze the situation in context, realize that one of the reasons why the activities are more frequent inbound than that outbound activities is because there are more companies making use of external knowledge while few companies release their internal knowledge. In other words, a certain company may even make available your knowledge to several companies simultaneously or not. Thus, an outbound activity designed will lead several inbound activities.

Beyond this possible explanation, Huizingh (2011: 4) still increase the problem

of measurement on information's from the empirical studies "... other potential explanations are that measurement scales, the respondents, or the samples in these studies are biased. Further research could clarify these issues."

Another important aspect to be noted are the different phases in which Open Innovation is to be used, according to company size. Some studies prove that small and medium enterprises (SMEs) tend to make use of open practices at more advanced stages of their innovation process, especially at the marketing stage (Lee *et al.*, 2010). The first empirical studies (Chesbrough, 2003; Christensen, Olesen and Kjaer, 2005) about the open innovation model addressed cases of large established companies in the market. However, reality has shown that SMEs have discovered this model a great opportunity for bridging the gap in the factors that were missing in the innovation process. Examples of this are new opportunities created for SMEs because they can develop innovations even without having the necessary technologies internally. Thus, the cooperation will enable them to offer innovations, using technology already developed by those who have skills or assets needed.

In the words of Vanhaverbeke and colleagues, "managing and organizing open innovation in SMEs is quite specific, and the lessons learned from open innovation in large firms are not readily transferable to the context of SMEs. These factors make the need for specific studies on open innovation in SMEs even more urgent" (Vanhaverbeke *et al.*, 2012: 10).

To finalize this section, it is mentioned once again the contribution of Dahlander and Gann's (2010) to conclude on the importance of internal and external knowledge. The authors affirm that internal knowledge is a necessary complement of opening to outside ideas. However, it is less obvious that external knowledge can be replaced by internal knowledge. This observation of the authors demonstrates the existence of some gaps that still exist in the literature of Open Innovation to be filled with the development of empirical studies. Huizingh refers that "since the early works of Chesbrough almost a decade ago, we have learned a lot about the content, context and process of open innovation. Nevertheless, much more research is needed" (Huizingh, 2011).

However, it is less obvious that external knowledge can be replaced by internal knowledge. This observation of the authors demonstrates the existence of some gaps still existing in the literature of Open Innovation to be filled with the development of empirical studies.

Social Network Analysis

The present Social Network Analysis had as main motivation to contribute to the review of existing literature on "Open Innovation", taking the intention of elucidating and presenting concrete information about the evolution of the concept over the years.

In this context, the Social Network Analysis is an interesting tool to analyze the origin of particular concepts and their interactions. Allows reflects on areas related to the underlying theme and what are the authors and institutions that are to be published on the subject. The identification of the issues complements the literature review and provides a better reflection and knowledge of the work that is being done by the world (Cândido, 2011)

In several areas of knowledge, there are many studies being published today on the subject, but it might be interesting identify the nature of these studies. As from the collection of this information it was possible to draw the graph of existing networks between different areas of knowledge that are addressing the concept of Open Innovation.

The study conducted by Dahlander e Gann (2010) entitled "*How Open is Innovation*" despite making use of information contained in a database of scientific articles differs to the issues discussed here. The authors established a criterion of choice for full reading articles that addressed the issue of how companies open their innovation processes and not through articles which appeared in the words "Open Innovation". Based on the analysis of the articles make an interesting literature review on the different types of opening (inbound and outbound innovation) and try to clarify the business strategies that are characteristic of each of these types.

The following is the methodology used and the main considerations found in Social Network Analysis conducted in the present study.

Metodology

Were analyzed 403 articles published in the database of the Science Direct containing the words "Open Innovation" during the years 2003 to 2011. The articles that appeared in search results have in some part of text the words "Open Innovation" and not only the articles that have these words as keywords. Thus, towards the method of collects of articles were considered all articles that contained the words Open Innovation, because one of the objectives of the analysis was to determine which areas are using this term.

The information was collected separately per year and organized into matrices, after in sequences was grouped into a single matrix (general). The following list is the information collected:

- Journals in which the articles were published
- Countries of origin of the authors of articles
- Keywords these articles
- Year of publication

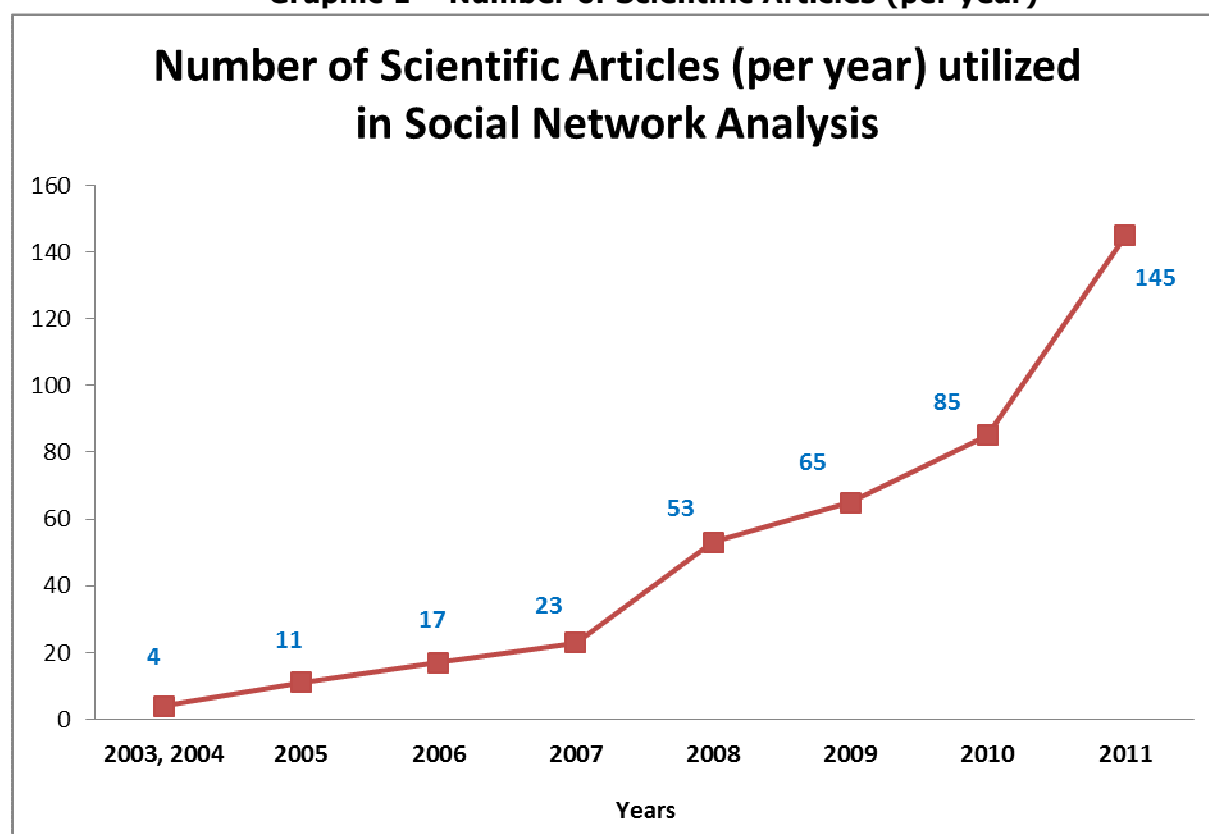
In the majority of articles such information could be obtained from observations of Abstracts. Only in some cases, depending on the format of presentation of the scientific journal, it was necessary to consult the full article. For articles that did not have keywords, these could not be considered for the analysis. It is noteworthy that there were few cases that needed to be disregarded sample.

The collection of information is done manually, which requires more effort and more time developing the matrix and then pass the information systematically in order to UCINET Software.

This Software although not very complex can make the task somewhat more selective, since it requires a certain standardization of the information matrix so that there is no distortion in the graph. For that reason, it was necessary to create a matrix that generally grouped data of all matrices which were prepared individually.

Graphic 1 shows the number of scientific articles published per year, indicating growth of the topic mainly in the more recent years. This situation was expected considering the intensive use of the concept of "Open Innovation" today by several knowledge areas.

Graphic 1 – Number of Scientific Articles (per year)



Source: Prepared by the author based on data obtained in Social Network Analysis (June, 2012)

The database *Science Direct* joins most large part of the major journals of the themes of innovation and technology management, taking high more visibility

in academia. In Social Network Analysis, were collected the number of articles published in each journal identified. Table 2 presents the ranking of journals that have more articles that contained the words "*Open Innovation*", among them: *Research Policy* (81); *Technovation* (73) e *Technological Forecasting and Social Change* (28)⁴.

Table 3 - Ranking of journals that have published more articles with the words "Open Innovation"

Journal	Number of Articles
Research Policy	81
Technovation	73
Technological Forecasting and Social Change	28
Industrial Marketing Management	14
European Management Journal	8
Journal of Engineering and Technology Management	8

Source: Prepared by the author based on data obtained in Social Network Analysis (June, 2012)

In order to observe what is the country of affiliation of authors who published articles noted in Social Network Analysis, we also collected information about the affiliation of the authors was that the identification header of the article below the author's name. Except some journals that presented this information at the end of the article. Among the countries with the highest number of authors, there is: United States (136); United Kingdom (123); Germany (109); Netherlands (87).

⁴ A complete list of the information presented in Tables 1 and 2 can be requested at the electronic address: a.candido@campus.fct.unl.pt

Table 4 - Countries with the largest number of authors in the articles analyzed

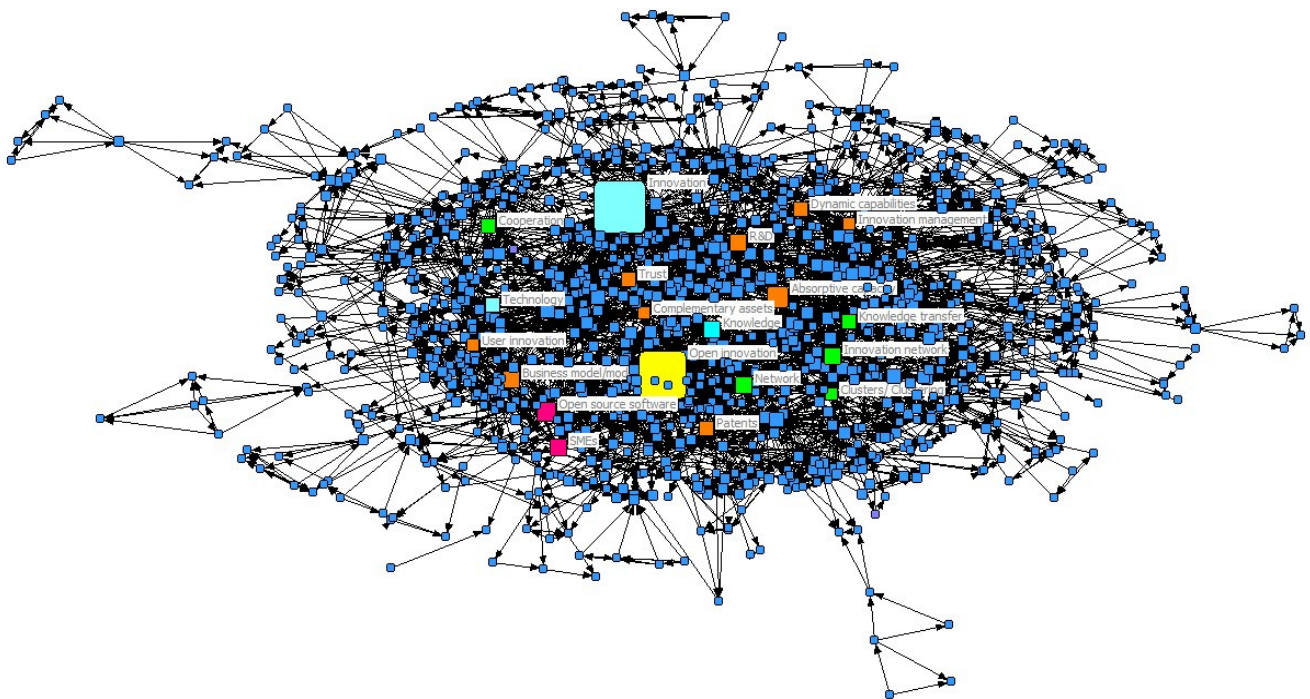
Countries	Number of Authors
United State	136
United Kingdom	123
Germany	109
Netherland	87
Finland	58
Italy	54
Belgium	45
Spain	42
Sweden	41
Taiwan	35
Switzerland	33

Source: Prepared by the author based on data obtained in Social Network Analysis (June, 2012)

Through the information obtained by the Social Network Analysis can confirm the multidisciplinary theme of "Open Innovation". We identified studies that used this term in various areas of knowledge. Addition to the innovation management, technology assessment, economics and sociology, were also identified articles related to computer engineering, nanotechnology, biotechnology, healthcare, electronics and software industry. As already expected most of the articles found, based on the methodology adopted for analysis were from the area of management and innovation studies. The same result was found in the analysis by Dahlander and Gann (2010), which has different criteria and objectives of the analysis presented here, as mentioned at the beginning of the section.

The Graphic 2 provides an illustration of check interactions between the keywords found in the articles considered for this analysis of social networks. The blue points are called Actors or Node and in this analysis are the keywords.

The sum of all of them represents the size of the network; in this case, as we can see, there is a network with a great representative of size. The interactions between nodes can be observed through the lines, called Node-Links, which are the ties that exist between two or more nodes. Every line of this is accompanied by an arrow that allows reader to check what it is the sense (origin and destination) of the interaction. These arrows are called Flow. Considering that it would not be possible to view the names of all the keywords due to the network size (number of actors), the keywords that appeared most frequently identified in the graphic. And so we can observe that the word "Innovation" features the larger squared, this means that the word was used more often and following "Open Innovation". The difference in the colors of the nodes is explained in the subject in whom they have been grouped together in an attempt to make a connection with existing theories behind the Open Innovation model. Consider the following:



Conclusions

It is meant that the proposed objectives of this study were achieved and thus the results of the Social Network Analysis applied to the words "Open Innovation" showed high growth and dissemination of the concept over the years. It had been found articles in various areas of knowledge, which represents certain interdisciplinary of the concept of Open Innovation. Beyond the innovation management, technology assessment, economics and sociology, were also identified articles related to computer engineering, nanotechnology, biotechnology, healthcare, electronics and software industry. This information confirms the attention to the concept that became a very attractive subject in academic and business environments.

From the perspective of the strategies of the Open Innovation model were presented two types of processes: Inbound and Outbound. The activities that correspond to each of these processes were briefly discussed and reflected gaps that still can be better exploited by companies.

In addition, as the result of empirical studies, Inbound activities are still more frequent than Outbound activities. Although there are some consistent arguments this explanation still lacks empirical observations.

Finally, it is expected that the results of this study can complement the State of the Art developments in Open Innovation model. Thereby, it is expected also to inspire future researchers and investigators to continue contributing to the construction of theoretical understanding and help in clarifying questions of managers.

References

- Cândido, A.C. 2012. Processo de Desenvolvimento e Difusão de Cloud Computing: Estudo sobre as Redes de Colaboração no Brasil, *IET Working Papers Series*, No. WPS05/2012, IET, 28 pp
- Chesbrough, H.M. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business School Press: Boston.
- Chesbrough, H.M. 2006, *Open Business Models: How to Thrive in the New Innovation Landscape*. Harvard Business School Press: Boston.
- Chesbrough, H.M. 2007. Why companies should have open business models. *MIT Sloan Management Review*, v. 48 (2), pp. 22-28.
- Chesbrough, H.M., Crowter, A.K. 2006. Beyond high-tech: early adopters of Open Innovation in other industries. *R&D Management*, v. 36, pp. 229-236.

- Chiaroni, D., Chiesa, V., Frattini, F. 2011. The Open Innovation Journey: How firms dynamically implement the emerging innovation management paradigm. *Technovation*, v. 31, pp. 34-43.
- Christensen, J.F., Olesen, M.H., Kjaer, J.S. 2005. The industrial dynamics of open innovation – evidence from the transformation of consumer electronics. *Research Policy*, v. 34, pp. 1533-1549.
- Cohen, W.M., Levinthal, D.A. 1989. Innovation and learning: Two faces of R&D. *The Economic Journal*, v. 99, pp. 569-596.
- Cohen, W.M., Levinthal, D.A. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, v. 35 (1), pp. 128-152.
- Dahlander, L., Gann, D.M. 2010. How open is innovation? *Research Policy*, v. 39, pp. 699-709.
- Huizingh, E.K.R.E. 2011. Open Innovation: State of the art and futures perspectives. *Technovation*, v. 31, pp. 2-9.
- Huston, L., Sakkab, N. 2006. Connect and develop: inside Procter & Gamble's new model for innovation. *Harvard Business Review*, v. 84, pp. 58-66.
- Kirschbaum, R. 2005. Open Innovation in practice. *Research Technology Management*, v. 48 (4), pp. 24-28.
- Lee, S., Yoon, B., Park, J. 2010. Open Innovation in SMEs – an intermediated network model. *Research Policy*, v. 39, pp. 290-300.
- Lichtenthaler, U., Lichtenthaler, E. 2009. A capability-based framework for open innovation: complementing absorptive capacity. *Journal of Management Studies*, v. 46 (8), pp. 1315-1388.
- Rumelt, R.P., Schendel, D., Teece, D.J. 1991. Strategic management and economics. *Strategic Management Journal*, v. 12, pp. 5-12.
- Teece, D.J. 1986. Profiting from technological innovation: implications for integration collaboration, licensing and public policy. *Research Policy*, v. 15, pp. 285-305.
- Vanhaverbeke et al. 2012. *Open Innovation in SMEs: How can small companies and start-up benefits from open innovation strategies?* Research Report: knowledge Partner.
- von Hippel, E. 1986. Lead Users: A Source of novel products concepts. *Management Science*, v. 32, pp. 791-805.
- von Zedtiwitz, M. Gassmann, O. 2002. Market versus technology driven in R&D internationalization: four different patterns of managing research and development. *Research Policy*, v. 31(4), pp. 569-588.